PROSTHETIC KNEE JOINT HAVING AT LEAST ONE DIAMOND ARTICULATION SURFACE

VI. Claims

We claim:

1. A prosthetic knee joint comprising:

a first joint member,

a first joint member bone fixation portion, said first joint member bone fixation portion being adapted to be securable to a bone,

a first joint member load bearing and articulation portion,

a first joint member polycrystalline diamond compact, said first joint member polycrystalline diamond compact serving to form at least a portion of said first joint member load bearing and articulation portion,

a first joint member polycrystalline diamond compact substrate, said substrate being located on said first joint member polycrystalline diamond compact,

a first joint member polycrystalline diamond compact diamond table sintered to said first joint member polycrystalline diamond compact substrate,

solvent-catalyst metal located in said first joint member polycrystalline diamond compact,

a first joint member gradient transition zone between said first joint member polycrystalline diamond compact substrate and said first joint member polycrystalline diamond compact diamond table, said first joint member gradient transition zone having a substrate side and a diamond table side, said first joint member gradient transition zone

having both solvent-catalyst metal and diamond therein, and said first joint member gradient transition zone exhibiting a transition of ratios of percentage content of solvent-catalyst metal to diamond from one side of said gradient transition zone to another side such that at a first point in said first joint member gradient transition zone near said substrate side, the ratio of percentage content of solvent-catalyst metal to diamond is greater than it is at a second point in said first joint member gradient transition zone closer to said diamond side than said first point,

chemical bonds between said first joint member polycrystalline diamond compact diamond table and said first joint member polycrystalline diamond compact substrate which tend to secure said diamond table to said substrate,

a mechanical grip between said first joint member polycrystalline diamond compact diamond table and said first joint member polycrystalline diamond compact substrate which tends to secure said diamond table to said substrate,

a first joint member load bearing and articulation surface, said first joint member load bearing and articulation surface including sintered polycrystalline diamond of said first joint member polycrystalline diamond compact, said sintered polycrystalline diamond providing a smooth and low-friction first joint member load bearing and articulation surface,

a second joint member,

a second joint member bone fixation portion, said second joint member bone fixation portion being adapted to be securable to a bone,

a second joint member load bearing and articulation portion,

a second joint member polycrystalline diamond compact, said second joint

member polycrystalline diamond compact serving to form at least a portion of said second joint member load bearing and articulation portion,

a second joint member polycrystalline diamond compact substrate, said substrate being located on said second joint member polycrystalline diamond compact,

a second joint member polycrystalline diamond compact diamond table sintered to said second joint member polycrystalline diamond compact substrate,

solvent-catalyst metal located in said second joint member polycrystalline diamond compact,

a second joint member gradient transition zone between said second joint member polycrystalline diamond compact substrate and said second joint member polycrystalline diamond compact diamond table, said second joint member gradient transition zone having a substrate side and a diamond table side, said second joint member gradient transition zone having both solvent-catalyst metal and diamond therein, and said second joint member gradient transition zone exhibiting a transition of ratios of percentage content of solvent-catalyst metal to diamond from one side of said gradient transition zone to another side such that at a first point in said second joint member gradient transition zone near said substrate side, the ratio of percentage content of solvent-catalyst metal to diamond is greater than it is at a second point in said second joint member gradient transition zone closer to said diamond side than said first point,

chemical bonds between said second joint member polycrystalline diamond compact diamond table and said second joint member polycrystalline diamond compact substrate which tend to secure said diamond table to said substrate,

a mechanical grip between said second joint member polycrystalline diamond

compact diamond table and said second joint member polycrystalline diamond compact substrate which tends to secure said diamond table to said substrate, and

a second joint member load bearing and articulation surface, said second joint member load bearing and articulation surface including sintered polycrystalline diamond of said second joint member polycrystalline diamond compact, said sintered polycrystalline diamond providing a smooth and low-friction second joint member load bearing and articulation surface.

2. A joint as recited in claim 1 further comprising topographical features on at least one of said substrates, said topographical features serving to enhance said mechanical grip between the substrate and its corresponding diamond table.

3. A joint as recited in claim 1 wherein said first joint member load bearing and articulation surface has a convex shape and wherein said second joint member load bearing and articulation surface has a concave shape.

4. A joint as recited in claim 1 wherein at least one of said first and said second joint member load bearing and articulation surface has an arcuate shape.

5. A joint as recited in claim 1 wherein at least one of said first and said second joint member load bearing and articulation surface has a hemispherical shape.

6. A joint as recited in claim 1 further comprising an interface present between at least one of said substrates and its diamond table.

7. A joint as recited in claim 1 further comprising solvent-catalyst metal present in said substrate.

8. A joint as recited in claim 7 wherein said solvent-catalyst metal present in said substrate is the same solvent-catalyst metal present in said diamond table.

9. A joint as recited in claim 1 further comprising interstitial spaces in at least one of said diamond tables.

10. A joint as recited in claim 1 further comprising solvent-catalyst metal located in at least one of said diamond tables.

11. A joint as recited in claim 1 further comprising a residual stress field in at least one of said polycrystalline diamond compacts, said residual stress field tending to enhance strength of said polycrystalline diamond compact.

12. A joint as recited in claim 1 wherein diamond in at least one of said polycrystalline diamond compacts has a coefficient of thermal expansion CTE_{Cd}, and wherein its corresponding substrate has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}.

13. A joint as recited in claim 1 wherein in at least one of said polycrystalline diamond compacts, the diamond has a modulus $M_{Cd,}$ and the substrate has a modulus M_{sub}, and wherein $M_{Cd,}$ is not equal to M_{sub}.

14. A joint as recited in claim 1 further comprising a crystalline diamond structure in at least one of said diamond tables.

15. A joint as recited in claim 1 wherein at least one of said load bearing and articulation surfaces has an Ra value of between about 0.01 to about 0.005 microns.

16. A joint as recited in claim 1 wherein at least one of said polycrystalline diamond load bearing and articulation surfaces is burnished.

17. A joint as recited in claim 1 wherein at least one of said first and said second joint member bone fixation portions is shaped to be press fit into a receptacle formed in a bone.

18. A joint as recited in claim 1 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior.

19. A joint as recited in claim 1 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior that includes features which enhance frictional engagement with a bone.

20. A joint as recited in claim 1 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior that permits osseointegration.

21. A joint as recited in claim 1 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior that includes a surface coating which encourages bone growth against said coating.

22. A joint as recited in claim 1 further comprising a bone mating surface on at least a portion the joint, said bone mating surface including a structure selected from the group consisting of metal mesh, porous metal, porous diamond, metal sintered beads, and plasma spray metal.

23. A joint as recited in claim 1 wherein at least one of said first and said second joint member bone fixation portions is shaped to permit bone fixation to be accomplished by use of at least one mechanical fastener.

24. A joint as recited in claim 1 wherein at least one of said substrates includes a metal alloy with at least one component of said metal alloy being selected

from the group consisting of titanium, aluminum, vanadium, molybdenum, hafnium, nitinol, cobalt, chrome, molybdenum, tungsten, cemented tungsten carbide, cemented chrome carbide, fused silicon carbide, nickel, tantalum, and stainless steel.

25. A joint as recited in claim 1 wherein at least one of said substrates includes CoCr as a solvent-catalyst metal.

26. A joint as recited in claim 1 wherein at least one of said substrates includes a plurality of substrate layers.

27. A joint as recited in claim 1 wherein at least one of said substrates includes at least two distinct substrate layers of different metals.

28. A joint as recited in claim 1 wherein at least one of said diamond tables includes diamond crystals of at least two different dimensions.

29. A prosthetic knee joint comprising:

a first joint member,

a first joint member bone fixation portion, said first joint member bone fixation portion being adapted to be securable to a bone,

a first joint member load bearing and articulation portion,

a second joint member,

a second joint member bone fixation portion, said second joint member bone fixation portion being adapted to be securable to a bone,

a second joint member load bearing and articulation portion,

a second joint member polycrystalline diamond compact, said second joint member polycrystalline diamond compact serving to form at least a portion of said second joint member load bearing and articulation portion,

a second joint member polycrystalline diamond compact substrate, said substrate being located on said second joint member polycrystalline diamond compact,

a second joint member polycrystalline diamond compact diamond table sintered to said second joint member polycrystalline diamond compact substrate,

solvent-catalyst metal located in said second joint member polycrystalline diamond compact,

a second joint member gradient transition zone between said second joint member polycrystalline diamond compact substrate and said second joint member polycrystalline diamond compact diamond table, and

a second joint member load bearing and articulation surface, said second joint member load bearing and articulation surface including sintered polycrystalline diamond, said sintered polycrystalline diamond providing a smooth and low-friction second joint member load bearing and articulation surface.

30. A joint as recited in claim 29 further comprising solvent-catalyst metal located in said second joint member polycrystalline diamond compact.

31. A joint as recited in claim 29 wherein said a second joint member gradient transition zone is located between said second joint member polycrystalline diamond compact substrate and said second joint member polycrystalline diamond compact diamond table, and wherein said second joint member gradient transition zone has a substrate side and a diamond table side, said second joint member gradient transition zone having both solvent-catalyst metal and diamond therein, and said second joint member gradient transition zone exhibiting a transition of ratios of percentage content of solvent-catalyst metal to diamond from one side of said gradient transition zone to

another side such that at a first point in said second joint member gradient transition zone near said substrate side, the ratio of percentage content of solvent-catalyst metal to diamond is greater than it is at a second point in said second joint member gradient transition zone closer to said diamond side than said first point.

32. A joint as recited in claim 29 further comprising chemical bonds between said second joint member polycrystalline diamond compact diamond table and said second joint member polycrystalline diamond compact substrate which tend to secure said diamond table to said substrate.

33. A joint as recited in claim 29 further comprising a mechanical grip between said second joint member polycrystalline diamond compact diamond table and said second joint member polycrystalline diamond compact substrate which tends to secure said diamond table to said substrate.

34. A joint as recited in claim 33 further comprising topographical features on at least one of said substrates, said topographical features serving to enhance said mechanical grip between the substrate and its corresponding diamond table.

35. A joint as recited in claim 29 wherein said second joint member load bearing and articulation surface has a shape selected from the group consisting of concave, convex, arcuate, hemispherical and partially spherical.

36. A joint as recited in claim 29 further comprising a residual stress field said polycrystalline diamond compact, said residual stress field tending to enhance strength of said polycrystalline diamond compact.

37. A joint as recited in claim 29 wherein diamond in said polycrystalline diamond compact has a coefficient of thermal expansion CTE_{Cd}, and wherein said

corresponding substrate has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}.

38. A joint as recited in claim 29 wherein in said polycrystalline diamond compact, the diamond has a modulus $M_{Cd,}$ and the substrate has a modulus M_{sub}, and wherein $M_{Cd,}$ is not equal to M_{sub}.

39. A joint as recited in claim 29 wherein said second joint member load bearing and articulation surface has an Ra value of between about 0.01 to about 0.005 microns.

40. A joint as recited in claim 29 wherein said polycrystalline diamond load bearing and articulation surface is burnished.

41. A joint as recited in claim 29 wherein at least one of said first and said second joint member bone fixation portions is shaped to be press fit into a receptacle formed in a bone.

42. A joint as recited in claim 29 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior.

43. A joint as recited in claim 29 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior that includes features which enhance frictional engagement with a bone.

44. A joint as recited in claim 29 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior, said bone mating surface including a structure selected from the

group consisting of metal mesh, porous metal, porous diamond, metal sintered beads, and plasma spray metal.

45. A joint as recited in claim 29 wherein at least one of said first and said second joint member bone fixation portions includes a bone mating surface on at least a portion of its exterior that includes a surface coating which encourages bone growth against said coating.

46. A joint as recited in claim 45 wherein said coating includes hydroxyl apatite.

47. A joint as recited in claim 29 wherein at least one of said first and said second joint member bone fixation portions is shaped to permit bone fixation to be accomplished by use of at least one mechanical fastener.

48. A joint as recited in claim 29 wherein said substrate includes at least one metal selected from the group consisting cobalt, chrome, titanium, tungsten, molybdenum and iron.

49. A joint as recited in claim 29 wherein said substrate includes a metal alloy selected from the group consisting of titanium, titanium aluminum and vanadium, titanium molybdenum hafnium, titanium and nitinol, cobalt chrome, cobalt chrome molybdenum, cobalt chrome tungsten, cobalt chrome cemented tungsten carbide, cobalt chrome cemented chrome carbide, fused silicon carbide and stainless steel.

50. A joint as recited in claim 29 wherein said substrate includes a plurality of substrate layers.

51. A joint as recited in claim 29 wherein said substrate includes at least two distinct substrate layers of different metals.

52. A joint as recited in claim 29 wherein said diamond table includes diamond crystals of at least two different dimensions.

53. A joint as recited in claim 29 further comprising a first joint member load bearing and articulation surface, said first joint member load bearing and articulation surface including a counter bearing material against which said second joint member load bearing and articulation surface polycrystalline diamond may articulate.

54. A joint as recited in claim 53 wherein said counter bearing material includes a material selected from the group consisting of monocrystal diamond, natural diamond, polycrystalline diamond, CVD diamond, PVD diamond, cubic boron nitride, wurzitic boron nitride, ceramic, cobalt-chrome alloy, titanium alloy, nickel, vanadium, tantalum, hafnium, molybdenum, cemented tungsten carbide, niobium, zirconia ceramic, alumina ceramic, polymers, UHMWPE, PEEK, cross-linked polymers and sapphire.

55. A joint as recited in claim 29 wherein said first joint member load bearing and articulation surface counter bearing material is not as hard as said second joint member load bearing and articulation surface.

56. A prosthetic knee joint comprising:

a first joint member,

a first joint member bone fixation portion, said first joint member bone fixation portion being adapted to be securable to a bone,

a first joint member load bearing and articulation portion,

a second joint member,

a second joint member bone fixation portion, said second joint member bone fixation portion being adapted to be securable to a bone,

a second joint member load bearing and articulation portion,

a load bearing and articulation surface located on said second joint member load bearing and articulation portion, and

a volume of diamond located on said load bearing and articulation portion, said volume of diamond material forming at least a portion of said load bearing and articulation surface.

57. A joint as recited in claim 56 said volume of diamond comprises polycrystalline diamond and wherein said second joint member load bearing and articulation portion comprises a substrate to which said polycrystalline diamond is sintered.

58. A joint as recited in claim 57 further comprising a gradient transition zone between polycrystalline diamond and said substrate.

59. A joint as recited in claim 58 further comprising chemical bonds between said polycrystalline diamond and said substrate.

60. A joint as recited in claim 59 further comprising a mechanical grip between said polycrystalline diamond and said substrate.

61. A joint as recited in claim 60 further comprising topographical features on said substrate, said topographical features serving to enhance said mechanical grip between said substrate and said polycrystalline diamond..

62. A joint as recited in claim 59 wherein said polycrystalline diamond and said substrate comprise a polycrystalline diamond compact.

63. A joint as recited in claim 62 further comprising a residual stress field in said polycrystalline diamond compact, said residual stress field tending to enhance

strength of said polycrystalline diamond compact.

64. A joint as recited in claim 63 wherein said polycrystalline diamond has a coefficient of thermal expansion CTE_{Cd}, and said substrate has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}.

65. A joint as recited in claim 63 wherein in said polycrystalline diamond has a modulus $M_{Cd,}$ and said substrate has a modulus M_{sub}, and wherein $M_{Cd,}$ is not equal to M_{sub}.

66. A joint as recited in claim 56 wherein said diamond articulation surface has an Ra value of between about 0.5 to about 0.005 microns.

67. A joint as recited in claim 56 wherein said diamond is selected from the group consisting of natural diamond, monocrystal diamond, polycrystalline diamond, CVD diamond and PVD diamond.

68. A component of a prosthetic knee joint comprising:

a substrate that includes a solvent-catalyst metal,

a diamond layer sintered to said substrate,

a zone between said substrate and said diamond layer that has a composition gradient of decreasing solvent-catalyst metal content across said zone,

chemical bonds in said zone, said chemical bonds including diamond-to-diamond bonds in said diamond table, diamond-to-metal bonds in said gradient transition zone, and metal-to-metal bonds in said solvent-catalyst metal.

a mechanical grip between said diamond layer and said substrate which tends to secure said diamond layer to said substrate,

interstitial spaces in said diamond layer,

solvent-catalyst metal present in said interstitial spaces, and

a non-planar load bearing and articulation surface formed by said diamond layer.

69. A component as recited in claim 68 wherein sintered diamond in said diamond layer has a coefficient of thermal expansion CTE_{Cd}, and wherein said substrate has a coefficient of thermal expansion CTE_{sub}, and wherein CTE_{Cd} is not equal to CTE_{sub}.

70. A component as recited in claim 68 wherein said sintered diamond in said diamond layer has a modulus $M_{Cd,}$ and wherein said substrate has a modulus M_{sub}, and wherein $M_{Cd,}$ is not equal to M_{sub}.

71. A component as recited in claim 68 further comprising a residual stress field that tends to enhance the strength of attachment of said diamond layer to said substrate.

72. A component as recited in claim 68 further comprising substrate surface topographical features on said substrate.

73. A component as recited in claim 68 wherein said substrate includes a metal alloy with at least one component of said metal alloy being selected from the group consisting of titanium, aluminum, vanadium, molybdenum, hafnium, nitinol, cobalt, chrome, molybdenum, tungsten, cemented tungsten carbide, cemented chrome carbide, fused silicon carbide, nickel, tantalum, and stainless steel.

74. A component as recited in claim 68 wherein diamond layer comprises diamond feedstock that has diamond particles that have a dimension in the range of less than about 1 nanometer to more than about 100 microns.

75. A component as recited in claim 68 wherein said diamond load bearing and articulation surfaces is a continuous diamond surface.

76. A component as recited in claim 68 wherein said diamond load bearing and articulation surface is a discontinuous diamond surface.

77. A component as recited in claim 68 wherein said diamond load bearing and articulation surface is a segmented diamond surface.

78. A component as recited in claim 68 wherein a lip is present on said substrate in order to interlock said diamond layer to said substrate.

79. A component as recited in claim 68 further comprising CoCr solvent-catalyst metal in said diamond table interstitial spaces.

80. A component as recited in claim 68 further comprising a continuous gradient in said diamond layer.

81. A component as recited in claim 68 further comprising an incremental gradient in said diamond layer.

82. A component as recited in claim 81 wherein said incremental gradient includes a plurality of strata in said diamond layer, a first of said strata having characteristics which differ from those of a second strata.

83. A component as recited in claim 82 wherein said differing characteristics of said strata are selected from the group consisting of diamond particle size, diamond particle distribution, and solvent-catalyst metal content.

84. A component as recited in claim 68 further comprising an interface gradient.

85. A component as recited in claim 68 wherein said diamond layer has a thickness of from less than about 1 micron to more than about 3000 microns.

86. A component as recited in claim 68 wherein said component is configured for use in a sliding knee joint.

87. A component as recited in claim 68 wherein said component is configured for use in a prosthetic joint for total knee replacement.

87. A component for use in a prosthetic knee joint comprising:

a substrate,

a diamond layer sintered to said substrate,

interstitial spaces located in said diamond layer,

solvent-catalyst metal located in said interstitial spaces,

a zone that includes both sintered diamond and substrate, said zone having a composition gradient of solvent-catalyst metal content to diamond content, said gradient being selected from the group consisting of interface gradient, continuous gradient and incremental gradient,

chemical bonds in the component, said chemical bonds including diamond-to-diamond bonds in said diamond layer, diamond-to-metal bonds in said zone, and metal-to-metal bonds in said solvent-catalyst metal,

a mechanical grip between said diamond layer and said substrate which tends to secure said diamond layer to said substrate, and

a non-planar load bearing and articulation surface formed by said diamond layer.

88. A component as recited in claim 88 further comprising a lip of substrate material which serves to hold said diamond layer in place adjacent said substrate.

89. A component as recited in claim 88 further comprising a dovetailed interlock between said diamond table and said substrate.

90. A component as recited in claim 88 further comprising a lip on said substrate that interlocks said substrate with said diamond table.

91. A component as recited in claim 88 wherein at least some of said bonds are sp3 carbon bonds.

92. A component as recited in claim 88 wherein said diamond table includes a plurality of strata such that a first of said strata having characteristics which differ from those of a second strata.

93. A component as recited in claim 93 wherein said differing characteristics are selected from the group consisting of diamond particle size, diamond particle distribution, and solvent-catalyst metal content.

94. A component as recited in claim 88 wherein said diamond table is formed using CoCr as a solvent-catalyst metal.

95. A component as recited in claim 88 wherein said diamond table presents a non-planar diamond load bearing and articulation surface.

96. A component as recited in claim 88 wherein said interstitial spaces are filled with a metal.

97. A component as recited in claim 88 wherein said interstitial spaces are filled with solvent-catalyst metal.

98. A component as recited in claim 88 wherein said component is configured for use in a sliding knee joint.

99. A component as recited in claim 88 wherein said component is configured for use in a prosthetic joint for total knee replacement.

100. A component as recited in claim 88 wherein said component is configured for use as a unicomparmental prosthetic replacement.